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SUMMARY OF M60A1 TANK LEAKAGE TESTING.(U)
JUN 79 J M FERRITER, L J BEESON

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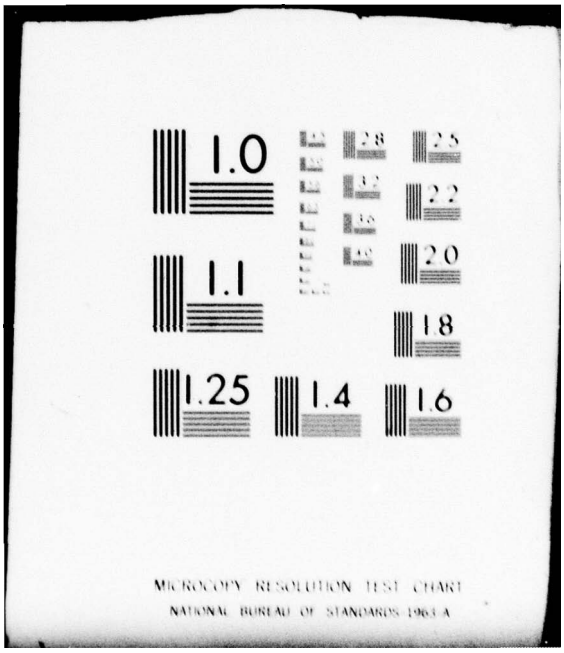
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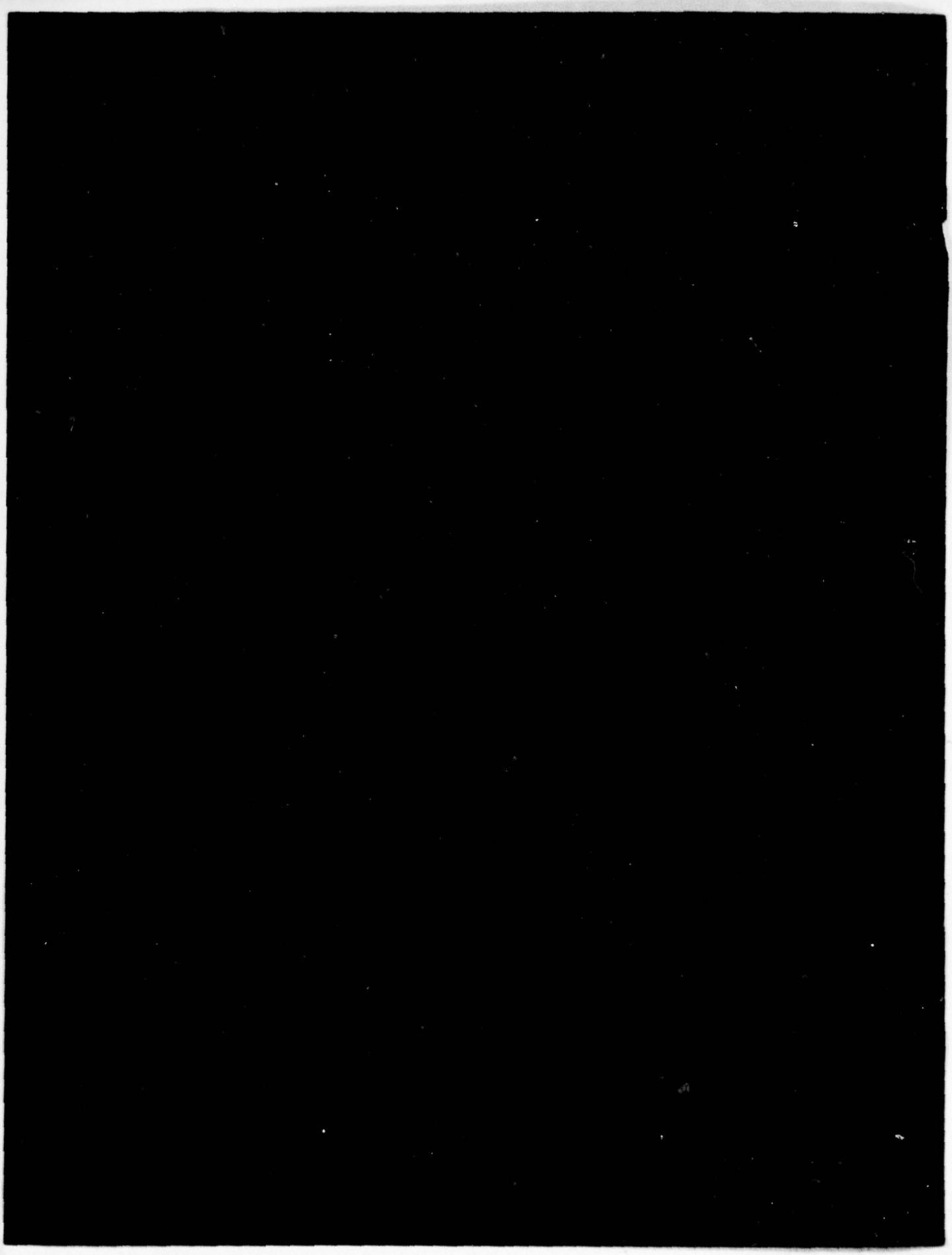

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This report summarizes four sets of M60A1 tank leakage data which were acquired from Honeywell, Inc., Aerophysics Co., Chrysler Corporation, and Chemical Systems Laboratory. Testing methodologies are reviewed and a standardized test procedure combining the various methodologies is suggested. Several proposed leak reduction measures are also presented.

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PREFACE

The work described in this report was authorized under Project 1M263721D604, NBC Collective Protection Program for Combat Vehicles. Work was carried out from September 1977 to July 1978.

The use of trade names in this report does not constitute an official endorsement or approval of the use of such commercial hardware or software. This report may not be cited for purposes of advertisement.

CONTENTS

SUMMARY OF M60A1 TANK LEAKAGE TESTING

I. INTRODUCTION.

The current Congressional concern to ensure adequate Nuclear/Biological/Chemical (NBC) protection for armored vehicles has resulted in the establishment of an armored vehicle program managed by Tank Automotive Research and Development Command (TARADCOM). Much of the central effort is at Chemical Systems Laboratory (CSL). Prior to determining armored-vehicle NBC vulnerability and recommending appropriate protective measures, a quantitative data base to include airflow, infiltration, purge, residual hazard and M13A1 filter unit must be generated. One of the first steps is to identify vehicle leakages. Once leak areas are identified, selective leak reduction measures to minimize NBC infiltration may be desirable. The objective of airflow (leakage) evaluation is to identify and quantify the magnitude of each leak area which allows air exchange between the crew compartment and the outside of the armored vehicle. The purpose of this report is threefold: (1) summarize four sets of M60A1 Tank leakage data which have been aquired from Honeywell, Inc., Aerophysics Co., Chrysler Corporation, and CSL, (2) review testing methodologies and select one method for future leakage testing, and (3) prepare preliminary modifications for major leak areas.

II. TEST PROCEDURES.

CSL supplies air through the commander's hatch with a centrifugal blower, and measures the flow rate with a calibrated-axial-vane anemometer immediately before discharge into the vehicle. The exterior and/or interior of the vehicle is then examined (generally by feel) to locate sources of air leakage which are then sealed with duct seal or tape. Once all accessible leaks are sealed, the unaccounted leakage is measured. Every attempt is made to reduce leakage to zero. Next, each individual leak is unsealed, and the associated leakage measured at several differential static pressures. Each leakage measurement is then repeated. The leak area is resealed prior to measuring the next leak area. Honeywell used the CSL method of leakage measurement.

Aerophysics supplies the air through the loader's hatch using a "code tester" built in accordance with the Joint Air Moving and Conditioning Association, Inc. – American Society of Heating, Refrigerating, and Air Conditioning Engineer's specifications published in April 1975. The "code tester" has the capability to measure airflow up to 6000 ft^3/min. The air mover is a variable speed centrifugal fan, controlled by a variable voltage-variable frequency "varidyne" electric generator. Initial leak identification is made using an ultrasonic air leak detector. After all accessible leaks are sealed with duct tape, the unaccounted leakage is measured. Next, each leak is unsealed and the associated leakage measured at several differential static pressures.

Chrysler Corporation supplies air through the vehicle ventilation blower inlet with a 2000-ft^3/min blower. The airflow is measured using a micromanometer while the crew compartment pressure is measured by an inclined-vertical manometer. To aid in leak source identification, an orange smoke flare is placed in the vehicle. Leaks are sealed using duct seal and tape. Beginning with the lowest leakage source, each leak is unsealed and the airflow rate is measured at several differential static pressures.

III. LEAKAGE DATA RESULTS.

The data from the four sources are summarized in the table. CSL and Aerophysics conducted their tests on the same M60A1 vehicles. The Chrysler and Honeywell data are from other M60A1 tanks. The CSL and Honeywell data are projected using a regression analysis.

IV. DISCUSSION OF RESULTS.

Individual leakage points are reported and are compared where applicable. All data are reported in standard cubic feet per minute at 1.5-inch water gage static pressure.

1. Total Vehicle Leakage.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
1028	1000	1347	1461	1613	1242	–

CSL's figure represents the total vehicle to include vehicle ventilation blower (no leaks sealed) with a round chambered. Aerophysics sealed the vehicle ventilation blower inlet, where Chrysler supplied air through the vehicle ventilation blower inlet. Tanks tested by Aerophysics, Chrysler, and Honeywell had various components (i.e., 7.62-mm coax machine gun, 50-caliber gun, range finders) missing when the vehicles were leak-tested. The vehicle ventilation blower is considered to be an air source, not a leak point and should be excluded from total leakage value. If the above corrections are made (appendix B), the comparative values are as follows:

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
947	971	871	995	1361	1058	–

2. Ejection Port, 50-Caliber.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
491	431	469	457	324	443	779

3. Turret Ventilation Blower

Aerophysics	CSL		Chrysler	Honeywell
–	SN8753	SN8946	–	SN2967
	476	466		662

Table. M60A1 RISE Leakage - Comparison of Results

(standard ft^3/min at 1.5-in water gage pressure)

Leak location	CSL* SN8753	CSL* SN8946	Aerophysics SN8753	Aerophysics SN8946	Chrysler SN4285	Chrysler SN8050	Honeywell* SN2967
As received	1347**	1461**	1028	1000	1613	1242	
50-cal. ejection port	469	457	491	431	324	443	779
Turret blower	476	466					662
Range finders (both)	138	143	146	145	138	130	326
7.62-mm gun port	83	94	143	144	136	123	
Cupola race	78	63			125	26	73
50-cal. access	71	93					
Unaccounted leakage	23	23	51	45	170	108	
Heater	18	17	15	12	17	17	
Main turret race	15	11			99	<17	3
Gunner's sight	6	12	7	7			
Bilge pump	2	2					
Cupola			146	165			
Driver vision plate			43		46	27	65
Commander hatch				29			65
Cupola rotor					117		
Main gun intersection					40		
Hatches, scopes, etc.					<56	17	

* Data projected from regression analysis.

** Round in breech

The 50-caliber ejection port and the turret ventilation blower are the largest leakage areas.

4. Main Gun Leakage, Breech Closed.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
369	372	374	368	–	–	–

TRADOC states that a round will normally be chambered when enemy contact is anticipated. Therefore, this leak area is not considered significant.

5. Port, 7.62-mm Machine Gun.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	–
143	144	83	94	136	123	

Aerophysics and Chrysler were measuring the port without a machine gun. CSL measured the leak with a demilitarized machine gun installed. The data indicate that on the average the leakage decreases by 37% when a gun is installed.

6. Range Finders (Both).

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8496	SN8753	SN8946	SN4285	SN8050	SN2967
146	145	138	143	138	130	326

Good agreement is obtained among Aerophysics, CSL, and Chrysler. Honeywell's measurement was without the range finders installed. The leakage through this port is 130% higher than with the range finders installed.

7. Cupola Race.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
–	–	78	63	125	26	73

Data show vehicle-to-vehicle variation. The average of all values is 73 ft^3/min.

8. Access Cover, 50-Caliber Machine Gun.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
–	–	71	93	–	–	–

9. Unaccounted for Leakage.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
51	45	23	23	170	108	–

This baseline leakage value depends on the effort made to identify individual leaks.

10. Driver's Vision Block Cover.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
43	0	–	–	46	17	65

If vision block was installed, the leakage is zero as indicated by SN8946, above.

11. Gunner's Sight.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
7	7	6	12	–	–	–

12. Personnel Heater Outlet.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
15	12	18	17	17	17	–

13. Main Turret Race.

Aerospace		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
–	–	15	11	99	–	3

Aerophysics measured the leakage with the turret ring seal inflated and determined that leakage is essentially zero.

14. Commander's Hatch.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
–	29	–	–	–	–	65

The difference between the two hatches could be due to the gasket or metal warpage.

15. Hull Drains.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
27	0	–	–	–	–	–

The hull drains have no measurable leakage when closed.

16. Main Gun Intersection.

Aerophysics		CSL		Chrysler		Honeywell
SN8753	SN8946	SN8753	SN8946	SN4285	SN8050	SN2967
–	250	–	–	40	–	–

The band sealing the mantlet to the main gun tube was loose on SN8946 when received. This was due to firing the main gun. The mantlet on SN4285 and SN2967 was deteriorated from age and cound not hold air. A plastic covering was placed over the mantlet.

V. LEAK REDUCTION MEASURES.

Proposed leakage reduction modifications were suggested by Donaldson Corp., Aerophysics, and CSL (after review of Chrysler leakage data). Definitive suggestions were presented by Donaldson Corp. encompassing those of Aerophysics and CSL. Therefore, only Donaldson's Corp. suggestions are presented:

1. For the 50-caliber ejection port, use a spring-loaded door covering the opening which would open after a given weight buildup and dump the brass.

2. The range finders generally leak through the pivot mechanism. Sealing washers could form an effective seal where the mechanism passes through the inside turret wall.

3. Felt gasketing around the edges of the 50-caliber access cover would reduce leakage and eliminate modification to the mantlet.

4. The cupola race may be more involved to reduce leakage; however, a grease seal or a felt or "bristle pad" seal could be used.

5. For the 7.62-mm machine gun port, an asbestos or silicone plug could be fit to seal the gap between the barrel extension and the port.

6. The gunner's sight is a small leak, but sealing should be easily accomplished with washers or gaskets between the sight and the turret.

7. The main gun-to-mantlet seal has been found to work loose when the gun is fired. A longer sealing neck with a molded lip and a wider band would help prevent this. The mantlet has also been found to deteriorate with age. Periodic inspections should be made and the mantlet replaced as required.

VI. CONCLUSIONS.

1. CSL, Chrysler, Aerophysics and Honeywell have similar approaches to leakage measurement.

2. M60A1 leakage data indicate the possibility for leak reduction. Modifications to the 50-caliber ejection port, range finder, 7.62-mm coaxial gun port, cupola race, 50-caliber access cover, gunner's sight and main gun-to-mantlet seal appear feasible.

3. A single method for future leakage testing can be established by a combination of CSL and Aerophysics test procedures and equipment.

4. The average leakage value using all data of the M60A1 as received with a round chambered is 1035 ft^3/min at 1.5-inches water gage. NOTE: Vehicle ventilation blower is not included in leakage value.

5. CSL and Honeywell data are projected using a regression analysis of actual measured data.

VII. RECOMMENDATIONS.

1. The test procedure should be standardized and followed for all vehicle leakage testing.

2. Standardized test equipment should be procured incorporating features of the Aerophysics' code tester, the CSL PR III (axial van anemometer) flow measurement device or other accurate airflow measurment instruments.

3. The seven above-mentioned "fixable leak points" should be examined for leakage reduction.

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1. Letter #19718, 26 September 1977, Warren Defense Division, Chrysler Corporation, Subject: Air Particulate Test.

2. Letter #19734, 29 September 1977, Warren Defense Division, Chrysler Corporation, Subject: Air Particlate Test.

3. Krisko, W. J., and Camplin, H. R. Donaldson Co., Inc. Final Report. Contract DAAK11-78-C0020. Investigative Study of Positive Pressure Collective Protection for Combat/Armored Vehicles. August 1978.

4. Jackson, W. P., Foshag, W. F., and Boehler, G. B. Aerophysics Company. Contract DAAK11-78-M-0013. Report 78-76-1. Static Air Leakage Assessment on Two M60 Tanks. 30 July 1978.

5. 1979 Honeywell Inc. Independent Research and Development Brochure.

APPENDIX A

LEAKAGE DATA TABLES

Table A-1. Chrysler Corporation Leakage Data - Vehicle M60A1 (SN4285)

Leakage point	Air leakage at 1.5-inches static-pressure water gage
	ft^3/min
Main gun intersection	40
Driver's vision block covers	46
Cupola race	125
Cupola rotor	117
Main gun tube	119
7.62-mm gun port	136
Rangefinder ports	138
.50-Cal. gun intersection	226
.50-Cal. ejection port	324
Personnel heater exhaust port	17
Driver's escape hatch	–
Front drain valve	–
Driver's IR scope	–
Loader's scope	56
Loader's hatch	–
Commander's hatch	–
Telescope port	–
Driver's hatch	–
Turret race	99
Residual leakage	170
Total	1613

NOTES:

1. Turret vent blower port used as pressurization port.
2. Leakage through the turret ring was measured as a separate item because of the leak-down rate of the ring seal in the test vehicle.
3. Floor access plates required sealing. RTV Sealant was used to seal around broken bolts.
4. Leakage at the personnel heater exhaust port was zero due to fuel trapped in the exhaust pipe.
5. The entire gun intersection was covered with plastic and tape for this test because of the deteriorated condition of the mantlet cover.

Table A-2. Chrysler Corporation Leakage Data - Vehicle M60A1 (SN8050)

Leakage point	Air leakage at 1.5-inches static-pressure water gage
	ft^3/min
Residual leak after sealing tank	108
Driver's escape hatch	–
Front drain valve	–
Main gun intersection	–
Driver's IR scope	–
Loader's scope	–
Loader's hatch	17
Turret ring seal	–
Commander's hatch	–
Telescope	–
Driver's hatch	–
Personnel heater exhaust port	17
Driver's vision block covers	27
Cupola race	26
Cupola rotor	51
Main gun tube	118
7.62-mm gun intersection	123
Rangefinder ports	130
50-mm gun intersection	182
50-mm ejection port	443
Total	1242

NOTE: Turret vent blower port used as pressurization port.

Table A-3. Honeywell Inc. Leakage Data - Vehicle M60A1
(SN2967)

Test point	Configuration	Flow rate					Slope	Total area	Delta area
		Static pressure (inches water gage)							
		ft^3/min						ft^2	
1	Base	0.35 52	0.80 92	1.00 108	1.30 129	1.65 152	0.692	0.0269	–
2	Heater outlet	0.35 67	0.80 112	1.00 130	1.30 157	1.65 174	0.628	0.324	0.0055
3	Tank commander's hatch	0.35 77	0.80 134	1.00 154	1.30 177	1.55 198	0.634	0.0379	0.0110
4	Driver's hatch	0.35 75	0.80 125	1.00 145	1.30 173	1.55 190	0.630	0.0362	0.0093
5	Base	0.40 64	0.80 95	1.00 115	1.30 133	1.65 154	0.625	0.0281	–
6	Driver's periscope	0.25 76	0.80 137	1.00 160	1.30 183	1.55 195	0.525	0.0392	0.0111
7	Turret thru fittings	0.40 64	0.80 103	1.00 121	1.30 149	1.60 160	0.681	0.0300	0.0019
8	Base	0.40 58	0.80 92	1.00 108	1.30 128	1.65 145	0.655	0.0266	–
9	Left range finder dome	0.25 79	0.80 162	1.00 188	1.30 210	1.55 233	0.5963	0.0456	0.0190
10	Right range finder dome	0.23 74	0.80 165	1.00 192	1.30 215	1.50 225	0.6083	0.0460	0.0194

Table A-3. (Contd)

Test point	Configuration	Flow rate: Static pressure (inches water gage)					Slope	Total area	Delta area
		ft^3/min						ft^2	
11	Empty gunner's IR periscope	0.10 132	0.20 287	0.40 414	0.65 555		0.747	0.2047	0.1781
12	Turret vent blower	0.10 136	0.20 231	0.40 319	0.60 399	0.85 488	0.580	0.1358	0.1092
13	Commander's machine-gun cartridge-ejection slot	0.10 157	0.20 242	0.40 352	0.60 444	0.75 506	0.5754	0.1493	0.1227
14	Base	0.65 67	0.80 84	1.00 96	1.30 113	1.70 133	0.6884	0.0235	–
15	Base - engine 550 rpm	0.30 181	0.80 208	1.00 215	1.30 235	1.55 236	0.1665	0.0548	0.0313
16	Base - engine 1250 rpm	0.30 180	0.80 208	1.00 213	1.30 230	1.50 242	0.1742	0.0548	0.0313
17	Base - engine 1800 rpm	0.30 194	0.80 214	1.00 223	1.30 234	1.45 244	0.1360	0.0564	0.0329
18	Base	0.43 58	0.80 89	1.00 104	1.30 124	1.60 140	0.6757	0.0258	
19	Machine gun evaluation slot	0.25 62	0.80 145	1.00 168	1.30 291	1.50 202	0.7676	0.0452	0.0194
20	Commander turret ring	0.20 62	0.80 143	1.00 165	1.30 192	1.60 203	0.6606	0.0397	0.0139
21	Gun boot	0.20 88	0.80 206	1.00 226	1.30 257	1.45 275	0.576	0.0562	0.0304
22	Main turret ring	0.50 67	0.80 91	1.00 105	1.30 129	1.70 146	0.651	0.0263	0.0005

Table A-4. CSL Leakage Data*
(Vehicle M60A1 - SN8753)

Leakage point	Flow rate					
	Static pressure (inches water gage)					
	0.5	1.0	1.5	2.0	3.0	6.0
	ft^3/min					
As received round in breech**	773	1097	1347	1558	1912	2714
50-Cal. ejection port	252	373	469	551	692	1023
Turret ventilation blower	233	366	476	575	749	1177
Main gun breech open	173	254	319	374	470	691
Range finders (both)	73	109	138	163	206	309
Main gun breech closed	67	99	124	146	184	272
7.62-mm machine-gun port	43	65	83	98	125	190
Cupola race	38	60	78	95	124	196
50-Cal. access cover	35	55	71	85	111	173
Unaccounted for leakage	9	16	23	29	41	73
Personnel heater outlet	9	14	18	22	29	48
Main turret race	6	10	15	19	28	54
Gunner's sight	3	5	6	8	11	19
Bilge pump outlet	1	2	2	3	4	7

NOTES:

* Data projected using a regression analysis of five points between 0.5 - 2.5 in static pressure water gage.

** Sum of individual components will not provide satisfying results when compared to total measure value because of cumulative error for each leak point and error for unaccounted leak.

Table A-5. CSL Leakage Data*
(Vehicle M60A1 - SN8946)

Leakage point	Flow rate					
	Static pressure (inches water gage)					
	0.5	1.0	1.5	2.0	3.0	6.0
	ft^3/min					
As received round in breech**	744	1139	1461	1743	2236	3422
50-Cal. ejection port	248	364	457	536	672	987
Turret ventilation blower	235	362	466	557	717	1104
Main gun breech open	167	248	313	368	464	689
Range finders (both)	76	114	143	169	214	318
Main gun breech closed	68	100	126	149	187	277
7.62-mm machine-gun port	49	73	94	111	141	212
Cupola race	30	47	63	76	100	160
50-Cal. access cover	48	72	93	111	142	217
Unaccounted for leakage	9	16	23	29	40	71
Personnel heater outlet	8	13	17	21	27	44
Main turret race	4	8	11	14	21	39
Gunner's sight	5	9	12	14	19	33
Bilge pump outlet	1	1	2	2	3	5

NOTES:

* Data projected using a regression analysis of five points between 0.5 - 2.5 in static pressure water gage.

** Sum of individual components will not provide satisfying results when compared to total measured value because of cumulative error for each leak point and error for unaccounted leaks.

Table A-6. Aerophysics Co. Leakage Data - Vehicle M60A1 (SN8753)

Leakage point	Flow rate					
	Static pressure (inches water gage)					
	0.5	1.0	1.5	2.0	2.5	3.0
	ft^3/min					
Total leakage, measured	573	826	1028	1193	1338	1471
50-Cal. ejection port*	288	397	491	573	636	701
Main gun breech open	184	252	316	369	413	457
7.62-mm machine gun port	82	118	143	164	183	198
Range finders (both)*	82	119	146	170	189	207
Cupola*	77	122	146	168	191	209
Main gun breech closed*	72	104	127	145	160	175
Driver's vision block cover plates*	25	36	43	49	55	59
Unaccounted for leakage*	22	36	51	67	83	100
Personnel heater outlet*	9	13	15	17	17	18
Gunner's sight*	4	6	7	7	8	8
Hull drains open (both)	14	20	26	27	30	32

* Items included in total leakage value.

Table A-7. Aerophysics Co. Leakage Data - Vehicle M60A1 (SN8946)

Leakage point	Flow rate					
	Static pressure (inches water gage)					
	0.5	1.0	1.5	2.0	2.5	3.0
	ft^3/min					
Total leakage, measured	554	810	1000	1178	1300	1425
50-Cal. ejection port*	247	351	431	499	569	609
Main gun breech open	179	259	320	372	415	455
7.62-mm machine gun port	84	118	144	166	183	201
Range finders (both)*	82	118	145	168	188	205
Cupola*	109	133	165	193	219	242
Main gun breech closed*	68	97	118	138	152	164
Unaccounted for leakage*	19	32	45	60	77	97
Personnel heater outlet*	7	11	12	14	16	16
Gunner's sight*	4	7	7	8	9	9
Main-Gun-to-Mantlet Seal Loose	123	175	223	250	285	310
Commander's hatch*	18	25	29	37	41	51
50-Cal. access cover partly opened	109	155	190	219	246	271

* Items included in total leakage value.

APPENDIX B

TOTAL LEAKAGE VALUES

1. Chyrsler data

   SN4285

   1613 - mantlet - driver vision block - main gun tube - (7.62-mm-installed)

   1613 - 40 - 46 - 119 - 47 = 1361 ft^3/min

   SN8050

   1242 - driver's vision block - (7.62-mm-installed) - main gun tube

   1242 - 27 - 39 - 118 = 1058 ft^3/min

2. Aerophysics data

   SN8753

   1028 + (7.62-mm-installed) - main gun tube - driver periscope lids

   1028 + 89 - 127 - 43 = 947 ft^3/min

   SN8946

   1000 - main gun tube + (7.62-mm-installed)

   1000 - 118 + 89 = 971 ft^3/min

3. CSL data

   SN8753

   1347 - vehicle ventilation blower

   1347 - 476 = 871 ft^3/min

   SN8946

   1461 - vehicle ventilation blower

   1461 - 466 = 995 ft^3/min

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